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Efficiency-Based Prioritization of Stakeholders Using Data Envelopment Analysis

Soheil Azizi[1], Reza Rasinojehdehi[2,*]

[1] Department of Accounting and Management, Allameh Tabatabae University, Tehran, Iran; soheilazizi@yahoo.com.
[2] Department of Industrial Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran; rezarasinojehdehi@yahoo.com.

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Abstract

This paper introduces a novel approach to stakeholder prioritization by employing Data Envelopment Analysis (DEA). The study utilizes five key criteria-stakeholder power, urgency, legitimacy, level of involvement, and project impact-to quantitatively evaluate stakeholder efficiency. DEA models tailored for each stakeholder are applied, yielding a comprehensive prioritization depicted in numerical form. The methodology showcased in this research harnesses the versatility of DEA in stakeholder analysis. The resulting prioritization aids project managers in strategic decision-making, offering valuable insights to enhance project success and minimize negative impacts. This paper contributes a practical and effective tool for project managers seeking to optimize stakeholder engagement and project outcomes.

Keywords: Stakeholder prioritization, Data envelopment analysis, Efficiency evaluation, Project management, Decision support.

1 | Introduction

Management of project stakeholders involves the processes necessary for identifying individuals, groups, or organizations that can impact or be impacted by the project so that the expectations of stakeholders and their impact on the project can be analyzed. Appropriate management strategies are then developed to facilitate effective engagement of stakeholders in project execution and decision-making.

Stakeholder management also focuses on effective communication with stakeholders to understand their needs and expectations, address emerging issues, manage conflicting interests, and foster appropriate interaction with stakeholders in project activities and decisions. Ensuring stakeholder satisfaction should be managed as a key project objective [1].

Project stakeholder management is a crucial aspect of project management, as it involves identifying, analyzing, and managing the individuals or groups that have an interest in the project or are affected by its outcome. The literature on project stakeholder management has evolved over the years, with a focus on understanding the importance of stakeholders, their influence on the project, and the

Corresponding Author: rezarasinojehdehi@yahoo.com

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strategies for effectively managing them. One of the key themes in the literature on project stakeholder management is the identification and classification of stakeholders. Authors have proposed frameworks for categorizing stakeholders based on their power, legitimacy, and urgency [2]. These frameworks help project managers prioritize stakeholders and tailor their communication and engagement strategies accordingly [3]. Another important aspect of project stakeholder management is the analysis of stakeholders' interests and concerns.

Sadaghiani et al. [4] and Shenhar et al. [5] emphasize the need for project managers to understand the motivations and expectations of stakeholders in order to manage their involvement in the project effectively. It involves conducting stakeholder analysis to identify their needs, expectations, and potential sources of conflict. The literature also emphasizes the importance of engaging stakeholders throughout the project lifecycle.

According to [6] effective stakeholder engagement involves communication, consultation, and involvement in decision-making processes. It not only helps to build trust and relationships with stakeholders but also ensures that their concerns and interests are taken into account in project planning and execution [7].

In terms of strategies for managing stakeholders, authors such as Wu [8] have highlighted the importance of developing stakeholder management plans and using tools such as stakeholder mapping and engagement matrices. These tools help project managers to identify the most appropriate communication channels and engagement activities for different stakeholder groups.

Overall, the literature on project stakeholder management emphasizes the importance of understanding, analyzing, and engaging with stakeholders in order to ensure project success. It provides valuable insights and practical strategies for project managers to effectively manage the diverse interests and influences of stakeholders throughout the project lifecycle. Kuchta et al. [9] integrates diverse stakeholder perspectives to ensure a comprehensive and inclusive evaluation process.

As the topic of project stakeholder management is a relatively new area that has opened up in project management, there are gaps observed in this field. In recent years, research on project stakeholder management has been initiated and is ongoing. Despite the conducted reviews, it is evident that the majority of research conducted in this domain has focused on providing tools for classifying stakeholders.

After reviewing various patterns for classifying project stakeholders, proposed a model for stakeholder classification in the project management office [10]. Apart from the issue of categorizing stakeholders, it is essential to prioritize project stakeholders so that their treatment in the project aligns with their priority and significance, and their needs are addressed based on this prioritization.

This article introduces the prioritization of stakeholders as a subprocess of the stakeholder identification process. The process is illustrated with a practical example using the Data Envelopment Analysis (DEA) technique. The continuation of the article involves a review of the DEA technique, the introduction of the stakeholder prioritization process, and its significance in stakeholder management. Finally, an example of stakeholder prioritization using the DEA technique is presented. The future results and research are also outlined in the following sections.

2 | Literature Review

2.1 | Project Management

Project management involves the application of knowledge, skills, tools, and techniques to project activities to meet project requirements. It encompasses various aspects such as project planning, execution,

monitoring, and control, ultimately aiming to achieve project objectives within defined constraints [10], [11].

2.2 | Project Stakeholders

Project stakeholders are individuals, groups, or organizations that can affect, be affected by, or perceive themselves to be affected by a project [12]. They play a crucial role in project success, and their diverse expectations and perspectives need to be considered in project evaluation and ranking [9], [12], [13].

2.3 | Data Envelopment Analysis

DEA is a method used for evaluating and comparing the efficiency of decision-making units, including projects. It involves the comparison of inputs and outputs to assess the relative performance of each unit, enabling the identification of efficient and inefficient projects [15]–[23].

2.4 | Integration of DEA and Project Stakeholders

The proposed modification of the DEA method in the paper emphasizes the importance of integrating stakeholder perspectives into project evaluation and ranking. This integration aligns with the evolving definition of project success, which includes subjective measures such as stakeholder satisfaction [24]. The modification allows for a comprehensive assessment of projects by considering the varying views and priorities of different stakeholders involved in the projects [25]–[27].

The gap in the literature for DEA and stakeholders, particularly in the context of prioritizing stakeholders using DEA, lies in the lack of comprehensive methodologies that integrate stakeholder perspectives into the DEA framework for project evaluation and ranking. While there is existing research on both DEA and stakeholder management, there is a need for a structured approach that explicitly considers the varying priorities and expectations of different stakeholders in the evaluation and ranking of projects using DEA.

3 | Data Envelopment Analysis

DEA is a common method for calculating the relative efficiency of multiple similar units. Various definitions of efficiency have been presented, generally involving the ratio of output to input, focusing on how resources are utilized and managed effectively. In cases where there are multiple inputs and outputs, efficiency is calculated as the weighted sum of input ratios [17].

Efficiency evaluation methods can generally be categorized into parametric and non-parametric approaches. Non-parametric methods are based on a series of mathematical optimizations used to calculate relative efficiency. One such non-parametric method is DEA, which optimizes through linear programming in a way that the objective function is the weighted ratio of outputs to inputs. In this article, the efficiency of each proposed project for an organization is calculated using the DEA technique [28].

DEA has diverse applications, most of which are related to economic issues. Research articles on DEA can generally be divided into two categories: 1) theoretical concepts and techniques, and 2) applications of the technique. In the application section, most articles are related to sectors such as banking, healthcare, higher education, agriculture, industry, and financial intermediation [29].

DEA is a non-parametric programming technique widely used to assess the efficiency of similar decision-making units. The goal is to achieve relative efficiency among decision-making units that have multiple inputs and outputs. Assuming there are n decision-making units with m inputs and s outputs,

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the relative efficiency of each decision-making unit is obtained by solving a fractional programming model [30].

DEA is one of the non-parametric planning techniques extensively used for evaluating the efficiency of similar units. The objective of this technique is to achieve relative efficiency among decision-making units that possess multiple inputs and outputs, assuming they are similar. Assuming there are n decision-making units with m inputs and s outputs, the relative efficiency of each decision-making unit is determined by solving a fractional programming model [31].

$$\begin{aligned}
&\text{MAX } z = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}}, \\
&\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_j x_{ij}} \leq 1, \qquad j=1,2, \dots ,n, \\
&u_r \geq 0, \qquad r=1,2, \dots, s, \\
&v_i \geq 0, \qquad i=1,2, \dots, m.
\end{aligned} \tag{1}$$

where j is the index of the decision-making unit, $j = 1, \dots, n$, r is the output index $r = 1, \dots, s$, i is the input index $i = 1, \dots, m$, y_{rj} is the output value of the r-th output for the i-th decision-making unit, x_{ij} is the input value of the i^{th} input for the j-th decision-making unit, and z is the efficiency score of the evaluated unit.

In the above model, the efficiency score for each unit is obtained by dividing the weighted sum of outputs by the weighted sum of inputs. This score is less than or equal to one, where a score of one indicates efficiency and a score less than one implies inefficiency.

Although new models of DEA are continually being developed, each specializing in specific aspects, they all share a common foundation based on a set of fundamental models designed by the method's founders. One such model is the "Charnes, Cooper, and Rhodes" (CCR) [31] model from 1978, which assumes Constant Returns to Scale (CRS) in its analysis of efficiency. This model is defined as follows:

$$\begin{aligned}
&\text{MAX } z = \sum_{r=1}^{s} u_r y_{ro}, \\
&\text{S.t.} \\
&\sum_{i=1}^{m} v_i x_{io} = 1, \\
&\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, \qquad j = 1,2, \dots, n, \\
&u_r \geq 0, \qquad r = 1,2, \dots, s, \\
&v_i \geq 0, \qquad r = 1,2, \dots, m.
\end{aligned} \tag{2}$$

4 | Prioritizing Stakeholders

The process of prioritizing stakeholders can be considered as a subprocess within the stakeholder identification process. The goal of prioritizing project stakeholders is to provide better and more effective facilitation for interacting with stakeholders and reducing the risk of their negative impact on the project. Ultimately, the output of this process can contribute to scheduling project report presentations and

improving the quality of these reports for impactful stakeholders. In *Fig. 1*, the position of the stakeholder prioritization process in project stakeholder management is illustrated.

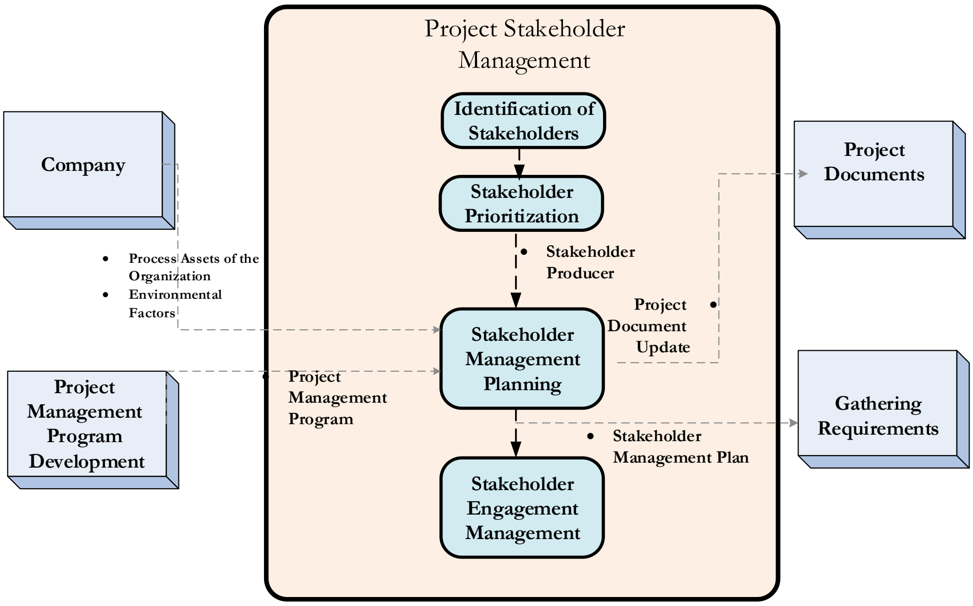

Fig. 1. Stakeholder prioritization data flow diagram.

In order to prioritize stakeholders, five criteria have been considered: power, urgency, legitimacy, level of stakeholder involvement, and Impact on project success. The first criterion is derived from the stakeholder salience model [32].

I. Stakeholder power: the ability of stakeholders to impose their demands on the project. The higher the stakeholder's power in imposing demands, the higher this criterion is.
II. Stakeholder urgency: some stakeholders require immediate attention, which can include following up on demands, regular periodic reporting, regular face-to-face meetings, etc. The higher the urgency of the stakeholder, the greater the need for attention.
III. Stakeholder legitimacy: this criterion determines the stakeholder's level of legal and obligatory engagement in the project.
IV. Level of stakeholder involvement: the current level of interaction from all stakeholders should be compared with the planned interaction level necessary for the project's successful completion. Stakeholder interaction throughout the project's life cycle is crucial for project success.
V. Impact factor on the project: the higher the stakeholder's impact on the project, the higher this criterion is. It is worth noting that this impact can be either positive towards project goals or negative, leading to project failure.

The number of inputs and outputs in the DEA technique varies based on the objective and type of process [16]. Since the ultimate goal of each project is to achieve its objectives and the success of key factors, three input criteria (power, urgency, legitimacy) and two output criteria (level of stakeholder involvement, impact on project) can be considered. Therefore, the problem has three input factors and two output factors.

How to quantify inputs and outputs: for the use of a quantitative model such as DEA, all criteria of the problem must be quantified [20]:

I. Stakeholder power: a scale from 1 to 5 is used for this criterion, where higher values indicate greater stakeholder power.
II. Stakeholder urgency: urgency is divided into four categories:

- *Communication with stakeholders based on their requests and with prior scheduled meetings. Reports are based on publicly available reports for stakeholders.*
- *Communication based on medium-term intervals (2 to 4 weeks).*
- *Meetings and reports at regular short-term intervals (1 to 2 weeks).*
- *Immediate need and attention, with meetings without prior notice and immediate response to stakeholder requests. Immediate reports are sent upon stakeholder request.*
- *Stakeholder legitimacy: stakeholders are classified into three categories, founders, internal, and External, based on the stakeholder identification and salience model. Numeric values from 3 to 1 are assigned to categories 1 to 3.*
- *Level of stakeholder involvement: according to the PMBOK classification (unaware, resistant, neutral, supportive, and leading), a scale from 1 to 5 is considered* [33].
- *Impact factor on the project: a scale from 0 to 10 is considered, with 10 having the highest impact on the project.*

5 | Numerical Example

Based on the theory of DEA, the number of units to be compared for their efficiency depends on the number of inputs and outputs. It cannot be less than a certain number. The relationship between the number of inputs, outputs, and stakeholders is as follows;

Stakeholders$\geq$ 3(input number+output number)

or

Stakeholders$\geq$ 2 $\times$input number$\times$output number.

Considering that in this article, 3 inputs and 2 outputs are defined for each stakeholder, the minimum number of stakeholders should be 12 or 15. The following numerical example is solved with the assumption of 20 stakeholders. *Table 1* shows the input and output data of stakeholder criteria.

Table 1. Input and output criteria of the example.

Stakeholder Code	Input Criteria			Output Criteria	
	V1 Stakeholder Power	V2 Stakeholder Urgency	V3 Stakeholder Legitimacy	U1 Level of Stakeholder Involvement	U2 Impact on the Project
A	3	3	3	4	2
B	3	1	2	5	10
C	4	3	2	5	1
D	2	2	3	3	5
E	5	1	3	5	5
F	2	1	2	5	4
G	2	3	1	3	8
H	5	1	2	4	10
J	5	4	2	2	4
K	5	1	2	3	8
L	2	1	2	5	5
M	4	3	2	3	7
N	3	1	2	3	8
O	5	2	2	4	4
P	2	2	1	2	9
Q	1	1	3	3	7
R	2	3	2	2	2
S	1	3	2	4	4
T	2	2	1	2	4
U	1	3	3	5	7

Based on the data in *Table 1*, a suitable linear model has been written for each stakeholder (according to *Model (2)*), and a total of 20 linear programming models have been solved. Microsoft Excel and the solver module were used for the solution. For example, the linear model for stakeholders with code A is as follows:

$$\text{MAX } z = 4u_1 + 2u_2,$$

Subject to:

$$4u_1 + 2u_2 - 3v_1 - 3v_2 - 3v_3 \leq 0,$$
$$5u_1 + 10u_2 - 3v_1 - 1v_2 - 2v_3 \leq 0,$$
$$5u_1 + 1u_2 - 4v_1 - 3v_2 - 2v_3 \leq 0,$$
$$3u_1 + 5u_2 - 2v_1 - 2v_2 - 3v_3 \leq 0,$$
$$5u_1 + 5u_2 - 5v_1 - 1v_2 - 3v_3 \leq 0,$$
$$5u_1 + 4u_2 - 2v_1 - 1v_2 - 2v_3 \leq 0,$$
$$3u_1 + 8u_2 - 2v_1 - 3v_2 - 1v_3 \leq 0,$$
$$4u_1 + 10u_2 - 5v_1 - 1v_2 - 2v_3 \leq 0,$$
$$2u_1 + 4u_2 - 5v_1 - 4v_2 - 2v_3 \leq 0,$$
$$3u_1 + 8u_2 - 5v_1 - 1v_2 - 2v_3 \leq 0,$$
$$5u_1 + 5u_2 - 2v_1 - 1v_2 - 2v_3 \leq 0,$$
$$3u_1 + 7u_2 - 4v_1 - 3v_2 - 2v_3 \leq 0,$$
$$3u_1 + 8u_2 - 3v_1 - 1v_2 - 2v_3 \leq 0,$$
$$4u_1 + 4u_2 - 5v_1 - 2v_2 - 2v_3 \leq 0,$$
$$2u_1 + 9u_2 - 2v_1 - 2v_2 - 1v_3 \leq 0,$$
$$3u_1 + 7u_2 - 1v_1 - 1v_2 - 3v_3 \leq 0,$$
$$2u_1 + 2u_2 - 2v_1 - 3v_2 - 2v_3 \leq 0,$$
$$4u_1 + 4u_2 - 1v_1 - 3v_2 - 2v_3 \leq 0,$$
$$4u_1 + 2u_2 - 3v_1 - 3v_2 - 3v_3 \leq 0,$$
$$2u_1 + 4u_2 - 2v_1 - 2v_2 - 1v_3 \leq 0,$$
$$3v_1 + 3v_2 + 3v_3 = 1,$$
$$u_i, v_i \geq 0.$$

The final results obtained from the execution of 20 stakeholder DEA models are provided in *Table 2*. *Fig. 2* represents the comparison of scores.

Table 2. The final responses of the prioritization stakeholder DEA model.

Stakeholder Code	Efficiency Score	Input Criteria			Output Criteria	
		Stakeholder Power	Stakeholder Urgency	Stakeholder Legitimacy	Level of Stakeholder Involvement	Impact on the Project
B	1	0.04	0.04	0.42	0.18	0.01
E	1	0.00	1.00	0.00	0.21	0.00
F	1	0.00	1.00	0.00	0.20	0.00
G	1	0.00	0.07	0.80	0.33	0.00
P	1	0.07	0.11	0.64	0.18	0.07
Q	1	0.39	0.61	0.00	0.00	0.14
L	1	0.00	0.05	0.48	0.20	0.00
H	1	0.00	0.27	0.37	0.00	0.10
S	1	0.27	0.00	0.36	0.22	0.03
U	1	0.29	0.09	0.15	0.09	0.08
C	0.92593	0.00	0.04	0.44	0.19	0.00
K	0.8	0.00	0.27	0.37	0.00	0.10
N	0.8	0.00	0.40	0.30	0.00	0.10
O	0.76923	0.00	0.04	0.46	0.19	0.00
T	0.71429	0.00	0.07	0.86	0.36	0.00
D	0.56395	0.23	0.11	0.10	0.11	0.05
M	0.55963	0.00	0.06	0.40	0.10	0.04
A	0.53333	0.07	0.00	0.27	0.13	0.00
R	0.4	0.20	0.00	0.30	0.18	0.02
J	0.35714	0.00	0.04	0.43	0.18	0.00

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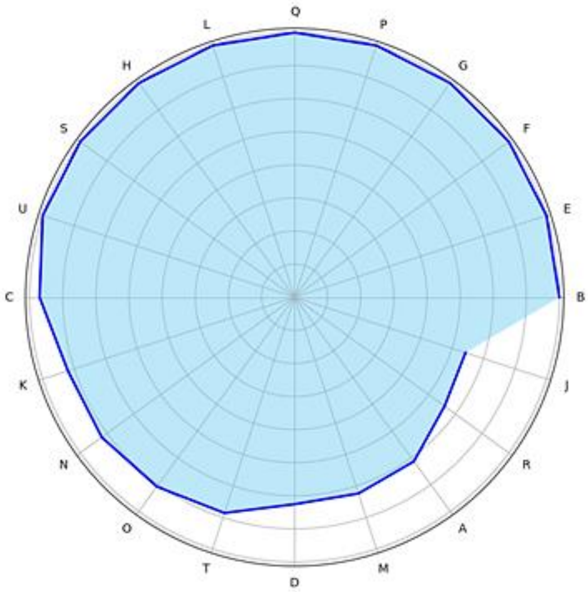

Fig. 2. Comparison of scores between stakeholders.

6 | Analyzing

Stakeholders are assigned efficiency scores ranging from 0 to 1, where 1 represents perfect efficiency. Stakeholders with scores closer to 1 are considered more efficient in utilizing resources and achieving objectives. Stakeholders B, E, F, G, P, and Q have perfect efficiency scores (1), indicating high efficiency. Stakeholders D, M, A, R, and J have efficiency scores below 0.5, suggesting relatively lower efficiency. Stakeholders C, K, N, O, and T have efficiency scores between 0.5 and 0.8, indicating moderate efficiency. Stakeholders S and U have efficiency scores above 0.8, suggesting relatively high efficiency but not perfect.

Different stakeholders prioritize input and output criteria differently. Stakeholder Q, for example, places significant importance on stakeholder urgency and level of stakeholder involvement. Stakeholder D, on the other hand, values stakeholder power and impact on the project more. Stakeholders with lower efficiency scores may require further attention or strategies to improve their impact on the project. Identifying key input and output criteria that significantly influence efficiency can guide targeted actions for improvement.

Overall, the DEA results can inform project managers about the efficiency of stakeholder engagement, allowing them to focus efforts on improving interactions with specific stakeholders and optimizing project outcomes.

7 | Conclusion

In summary, the application of DEA in prioritizing stakeholders has yielded insightful results. The study, guided by five key criteria - stakeholder power, urgency, legitimacy, level of involvement, and project impact, meticulously evaluates the efficiency of each stakeholder. The DEA models, intricately designed and solved for each stakeholder, underscore the robustness of the analytical approach. The final prioritization offers a comprehensive overview of stakeholder efficiency, facilitating informed decision-making for project managers. This research not only advances the utilization of DEA in stakeholder prioritization but also emphasizes the importance of considering various dimensions to optimize project success while minimizing adverse effects. The proposed methodology emerges as a valuable asset for project managers aiming to strategically engage stakeholders and navigate potential challenges across the project lifecycle.

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